Performance of Painted Plywood and Cloth Nzi Traps Relative to Manitoba and Greenhead Traps for Tabanids and Stable Flies

STEVE MIHOK[1] AND DAVID A. CARLSON[2]

J. Econ. Entomol. 100(2): 613–618 (2007)

ABSTRACT Experiments were conducted to adapt the cloth Nzi trap to a format suitable for fixed applications in biting fly sampling or control. Catches of tabanids [*Tabanus* L., *Chrysops* (Meigen), and *Hybomitra* Enderlein], and stable flies [*Stomoxys calcitrans* (L.)] in painted plywood traps were compared with those in standard phthalogen blue cloth traps, and in similarly painted cloth traps. The Manitoba horse fly trap and the *Tabanus nigrovittatus* Macquart "greenhead" box trap were used as additional standards during one tabanid season. Shiny features of traps reduced catches, e.g., paint on cloth instead of wood, or use of aluminum screening instead of netting. Nevertheless, appropriately painted plywood Nzi traps caught as many biting flies as did standard cloth Nzi traps, if paint finishes were matte, and with the use of phthalogen blue colorants. Nzi traps collected about the same tabanid fauna as the Manitoba and *T. nigrovittatus* traps, but with improved catches of *Chrysops* and *Tabanus*. Recommendations are provided on appropriate color matching, and selection of readily-available materials for trap construction.

KEY WORDS tabanids, stable fly, Nzi trap, Greenhead trap, Manitoba trap

Stable flies, *Stomoxys calcitrans* (L.), and tabanids are serious pests of livestock with few cost-effective options for their control (Foil and Hogsette 1994). Stable flies (Cilek 2002) and certain horse flies (Wall and Doane 1980) and deer flies (Cilek and Medrano 2000) also can be annoying pests of people. In the absence of practical mechanical traps, insecticides and adhesive-coated devices are typically used for biting fly control, (e.g., for stable flies and horn flies, see Steelman et al. 2003, Kaufman et al. 2005). For tabanids, box traps have a long history of use for greenhead control (Hayes et al. 1993). The Horse Pal and Epps traps also are available at the retail level for tabanids (Stringham 2001), but little is known about their efficacy.

In Africa, a simple mechanical trap, the Nzi, was developed several years ago with good collection efficiency for tsetse and other biting flies (Mihok 2002). The Nzi trap is also effective for biting flies in North America (Mihok et al. 2006, 2007). This 1-m triangular blue/black cloth trap with two blue wings kills flies passively, without the use of insecticides or adhesives. Research was therefore conducted to develop a Nzi trap format suitable for fixed applications, by using only readily available, retail products. Here, we report on the collection performance of painted plywood Nzi traps for biting flies compared with standard Nzi cloth traps, and a few conventional tabanid traps.

[1] 388 Church Street, Russell, Ontario, Canada K4R 1A8.
[2] Corresponding author: USDA–ARS, Center for Medical, Agricultural and Veterinary Entomology, 1600 SW 23rd Dr., Gainesville, FL 32608 (e-mail: dcarlson@gainesville.usda.ufl.edu).

Materials and Methods

Field studies were conducted in a turfgrass area on a 0.5-ha rural, residential property with scattered trees and adjacent woodlots at Russell, Ontario, Canada (45° 15′ N, 75° 21′ W). More details of the area and general methods are provided by Mihok et al. (2006).

Traps. Plywood Nzi traps were made to the same format and were set in the same way as cloth Nzi traps, ≈6 cm from ground surface (Fig. 1). Five 45.7- by 91.4-cm panels (0.95 cm in thickness), exterior-grade plywood were connected with strapping hinges to form the front and sides of the trap. Hinges were used to permit flat storage off-season; gaps were closed when the trap was set. White splined aluminum window screen framing (base of cone), and plastic molding (sides) were bolted to the plywood for attachment of netting. The splined framing extended to the top back corner; edges were beveled and fixed with a bolt to a 1.5- by 1.5-cm hardwood gardening stake pounded 10 cm into the ground to stretch the netting. A trapezoidal piece of plywood with a netting insert was used for the inner horizontal shelf. The shelf was attached to the front and sides of the trap with small right-angle braces to provide rigidity.

A Manitoba (MA) horse fly trap (Thorsteinson et al. 1965), and a *Tabanus nigrovittatus* Macquart "greenhead" (GH) trap (Hayes et al. 1993) were tested as conventional controls during one tabanid season to compliment a previous test of a standard cloth canopy trap (Mihok et al. 2006). The MA trap was set 70 cm off the ground with a large glossy black ball (75 cm in diameter), as in the original design, but with a clear

Fig. 1. Experimental plywood Nzi trap. The netting at the top and the back was fixed to the front and sides using splined aluminum framing or plastic molding bolted to the edges of the wooden panels. The top netting was suspended by thin wires hooked onto a clear plastic funnel inserted into the apex of the cone. A cut-off plastic bottle with a netting sleeve was used for daily collection of flies. The trapezoidal plywood horizontal inner shelf with netting is not visible.

polyvinyl chloride pyramidal canopy instead of a polyethylene cone (Schreck et al. 1993). The trap had a wide-mouth, funnel-shaped exit inserted into a 4.8-liter clear plastic jar, without insecticide.

The GH trap consisted of a 70- by 70- by 60-cm plywood box set 70 cm in height, black on the inside, open underneath, and with a charcoal aluminum screening inner baffle. This trap is currently used on Cape Cod, MA, for greenhead control (G. Sakolsky, personal communication). Our GH trap was painted phthalogen blue instead of royal blue and equipped with an upper pyramidal net and collector similar to that of the Nzi trap to monitor daily catches (Hayes et al. 1993). A glossy black ball decoy (45 cm in diameter) was added to the trap for one experiment. Except for being blue on the outside, the GH trap with a decoy is very similar in configuration to the commercially available Horse Pal trap (Newman Enterprises 2006).

Paints. Paints were prepared or purchased to match blue fabrics that are attractive to tsetse and biting flies (Mihok et al. 2006). Color matching was based on spectra obtained with a USB 2000 fiber optic spectrophotometer (Ocean Optics Inc., Dunedin, FL) by using a simple apparatus (Cilek 2003). Spectra were standardized for 100% reflectance with barium sulfate. Spectra for target fabrics, including a genuine sample of 4% phthalogen blue IF3GM (Dystar Textilfarben GmbH, Frankfurt, Germany), are provided in Fig. 2; spectra for matching paints are in Fig. 3. Only flat (<5% gloss at 60°) exterior acrylic latex paints were used. One black was used throughout (Beauti-Tone, Home Hardware, Burford, Ontario, Canada).

To match the dark phthalogen blue of the Nzi cloth trap (Kenyan fabric #1b, Mihok 2002), dark CuPc (copper phthalocyanine) paint was prepared by adding CuPc to Beauti-Tone clear base (2%, wt:vol). To match the brighter phthalogen blue cloth more typical of traps used in Zimbabwe and Ethiopia (fabric #26; Mihok 2002), a bright CuPc paint was prepared by adjusting this color with CuPc artist's acrylics (6% phthalo blue, 8% white, vol:vol; matched by eye). To test a similar bright generic paint, a colorimetry-matched custom color was purchased in Beauti-Tone paint (4.8% blue, 1.8% white, 0.8% magenta, 0.7% thalo green, vol:vol). Lastly, three Benjamin Moore (BM) Color Preview colors (Montvale, NJ) in MoorLife exterior acrylic latex flat enamel (deep base #105 3B) were purchased. Two colors were good matches to phthalogen blue: Brilliant Blue (#2065-30, match to bright cloth), and Evening Blue (#2066-20, match to dark cloth). A third BM color (Laguna Blue, #2059-30) was a reasonable match to cloth dyed with Procion Turquoise M-G (C.I. Reactive Blue 140), a sulfonated CuPc (Mihok et al. 2006).

Experiments. Experiments were either paired comparisons of a painted Nzi trap to a standard Nzi cloth trap (STD), or replicated Latin square designs, when more than one trap was tested. The standard was a phthalogen blue IF3GM cotton trap with white polyester mosquito netting (Mihok et al. 2006). Traps were baited with 1-octen-3-ol (Biosensory Inc., Willimantic, CT); new baits were used for each test. Experiments were conducted with an increasing variety of traps through 2004/5 as the efficacy of painted traps became evident (Table 1). Custom-prepared CuPc paints were tested initially, followed by undisclosed retail formulations. Dark and bright painted cloth traps also were tested; only the blue cloth was painted. Paint had a matte finish on wood and a shiny finish on cloth. We did not have the appropriate device to quantify gloss, but the difference was obvious to the eye.

In 2005, the MA and GH traps were operated continuously from 31 May to 1 August, whether part of an experiment or not. To compare the tabanid fauna sampled relative to Nzi traps, data were tabulated for the same dates for catches obtained in any type of Nzi trap, i.e., for painted and phthalogen blue Nzi traps set simultaneously in 2004/2005, and for minor variations on cloth Nzi traps set previously at the same site from 2001 onward (Mihok et al. 2006, 2007).

Florida. One experiment was conducted at the Center for Medical, Agricultural and Veterinary Entomology in Gainesville, FL (29° 41′ N, 82° 16′ W) on warm days (>20°C) in winter 2004. The objective was to test the attractiveness of BM paints relative to a phthalogen blue retail fabric (Sunbrella Pacific Blue acrylic awning fabric, Glen Raven Mills, Glen Raven, NC). The test used 4- to 9-d-old, laboratory-reared stable flies (Hogsette 1992) that were released into a large, screened enclosure (10 m in width by 20 m in length by 7 m in height). Stable flies were captured with arbitrary box-frame, plywood sticky traps (open top and bottom). Each box had three painted sides, with

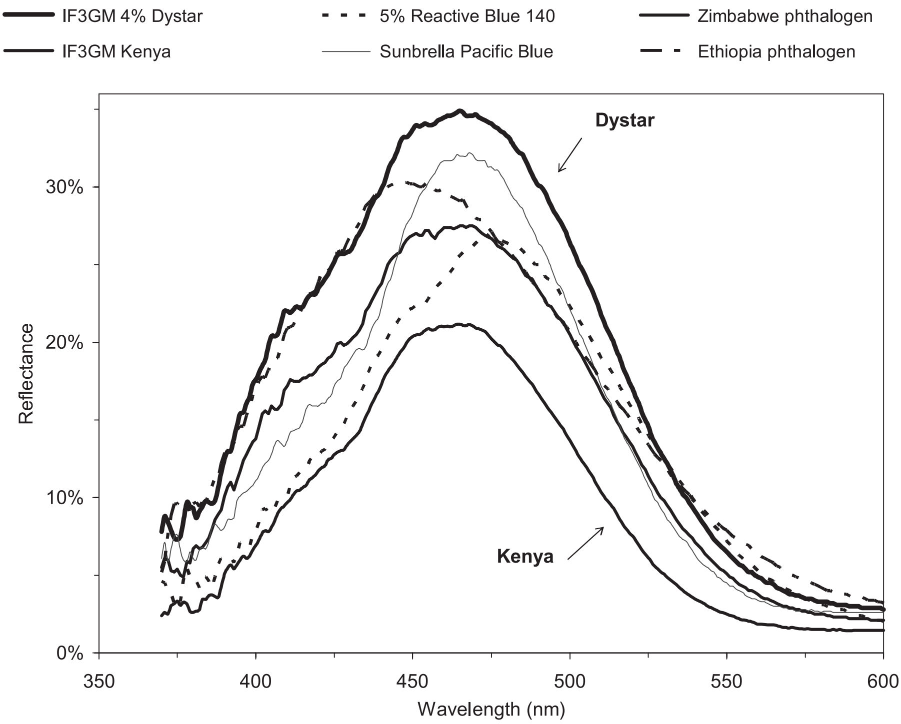

Fig. 2. Percentage of reflectance of fabrics dyed with variants of CuPc. Genuine samples of phthalogen blue IF3GM cotton drill from Mount Kenya Textiles and Dystar Textilfarben GmbH are contrasted with similar phthalogen blue cottons produced in Ethiopia and Zimbabwe with undisclosed processes, and Sunbrella Pacific Blue acrylic awning fabric. The other sample is cotton dyed greenish-blue with sulfonated CuPc (Procion Turquoise M-G or C.I. Reactive Blue 140). The Ethiopian cloth differs from other fabrics in having sharply rising reflectance above 700 nm, reaching 31% at 750 nm.

the fourth side covered by Sunbrella cloth. An adhesive-treated transparent sheet (Olson Products, Medina, OH) covered each outside surface. Each box was 31 by 62 cm on a side, set 31 cm from ground surface. The experiment consisted of eight 4 by 4 Latin squares (four paints/cloth $\times$ 4 compass directions) with each box rotated 90° each day for 8 d. From 96 to 547 stable flies were released each day.

Statistical Analyses. Catches x were transformed as $y = \log(x + 1)$ for statistical analysis (paired t-test or analysis of variance [ANOVA]). Proportionate changes in catch were summarized relative to a standard cloth Nzi trap (STD) in terms of the response ratio (R) (Hedges et al. 1999). This ratio is the same as the catch index or index of increase. It is the ratio of the geometric mean (10^y) of the experimental treatment (GM_t) to the geometric mean of the control (GM_c). Results are given as R (lower 95% CI, upper 95% CI based on a priori comparisons). Geometric mean catches in flies per trap per day also are given for the control ($GM_t = R \times GM_c$).

Results

Results are summarized in Fig. 4 for tabanids and then for stable flies in experimental sequence. A dark CuPc-painted plywood trap with shiny aluminum screening (experiment 1; $GM_c = 8.3$) and a similarly painted cloth trap, but with a shiny texture (experiment 2; $GM_c = 7.2$), caught significantly fewer tabanids than a STD trap. After replacement of the screening with white polyester netting, the dark CuPc plywood trap caught as many tabanids as a STD trap (experiment 3; $GM_c = 8.4$). This same trap, repainted in bright CuPc, caught as many tabanids as a STD trap (experiment 4; $GM_c = 3.2$). A new plywood trap custom painted to match bright CuPc caught as many tabanids as a STD trap (experiment 5; $GM_c = 2.1$). In the same experiment, the similarly painted cloth trap with a shiny texture caught significantly fewer tabanids.

In the next season, plywood traps in four blue paints, including a second test of the original bright CuPc trap, all caught statistically equivalent numbers of tabanids relative to each other (experiment 8; $GM_c = 4.7$). However, traps with additional tints (i.e., Laguna Blue, thalo green; Evening Blue, magenta) caught significantly fewer tabanids than a STD trap. The BM Brilliant Blue trap was tested again in experiment 10 and caught as many tabanids as a STD trap ($GM_c = 2.9$). Across all tests, proportionate catches of tabanid genera were similar from painted plywood traps and STD traps (paint versus cloth, 63 versus 67% *Tabanus* L., 31% versus 30% *Chrysops* (Meigen), 6% versus 3% *Hybomitra* Enderlein ($\chi^2 = 5.6$; df = 2; $P = 0.06$; $n = 1{,}067$).

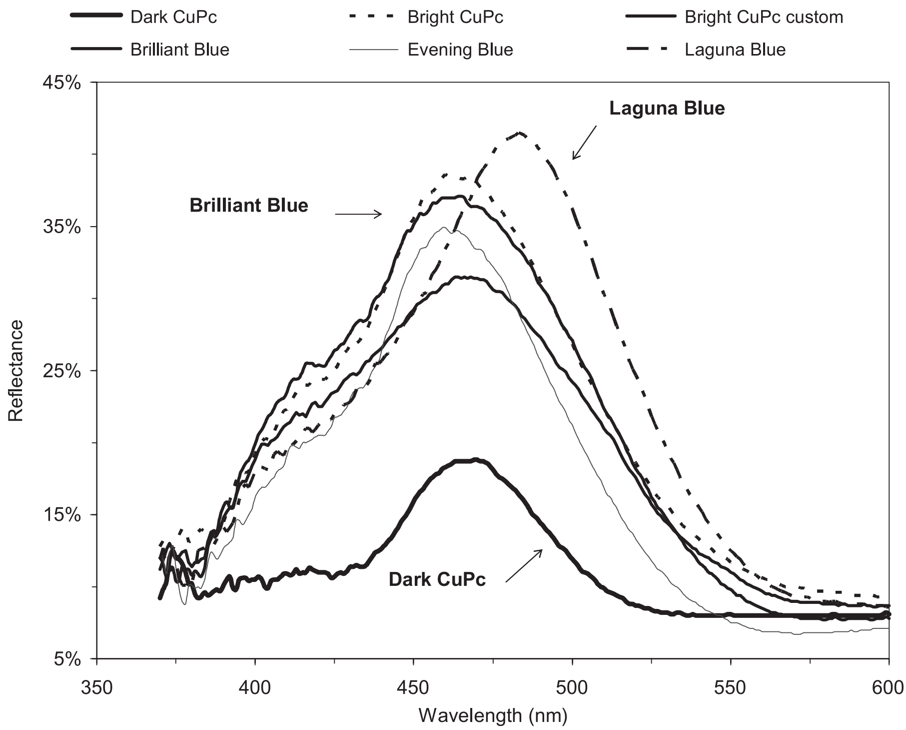

Fig. 3. Percentage of reflectance of dark and bright exterior acrylic latex paints containing only copper phthalocyanine (CuPc, Pigment Blue 15) relative to a custom retail match to bright CuPc, and relative to three Benjamin Moore Color Preview colors (Brilliant Blue, Evening Blue, and Laguna Blue). Note the change in scale on the y-axis relative to Fig. 2.

The GH trap in experiment 8 (Fig. 4), captured only eight *Chrysops* and no *Tabanus* or *Hybomitra* over 15 d, whereas the other conventional traps caught up to 35 *Chrysops* and 19 horse flies per day. When the GH trap was equipped with a black ball (experiment 9; GM_c = 3.3), there was a major improvement in catch. The trap now caught as many tabanids as a STD trap. *Tabanus similis* Macquart was present in both experiments, demonstrating poor performance without a decoy and improved performance with a decoy. The MA trap caught as many tabanids as a STD trap in both experiments.

Table 1. Details of experiments and traps tested relative to a standard phthalogen blue cloth Nzi trap (STD) at Russell, Ontario, Canada

Exp	*n* (d)	Trap
1	27	Nzi Dark CuPc (wood, with shiny metallic screening)[a]
2	18	Nzi Dark CuPc (painted cloth, with a shiny texture)
3	13	Nzi Dark CuPc (wood, with white polyester netting)
4	24	Nzi Bright CuPc (wood)
5	24	Nzi Bright CuPc custom (wood)
		Nzi Bright CuPc custom (painted cloth, with a shiny texture)
6	18	Nzi Bright CuPc custom (wood)
7, 11	24	Nzi Bright CuPc (wood)
8	15	Manitoba trap, greenhead trap without a decoy Four types of plywood Nzi traps: Bright CuPc, Benjamin Moore Brilliant Blue, Evening Blue, or Laguna Blue
9	20	Manitoba trap, greenhead trap with a black ball decoy
10	14	Nzi Benjamin Moore Brilliant Blue (wood)

With the exception of two painted cloth traps, all Nzi traps were plywood traps. Note one trap with aluminium screening instead of netting. CuPc, copper phthalocyanine; custom, Beauti-Tone custom color.

[a] Retail, highly transparent black aluminum window screening substituted for all netting.

Low catches precluded robust statistical comparisons by tabanid species in experiments 8 and 9. Qualitative differences in fauna were nevertheless apparent from all seasonal trapping (Nzi 2001–2005: 8,407 tabanids in 1,318 trap-days; MA 2005: 273 tabanids in 58 trap-days; and GH 2005: 98 tabanids in 58 trap-days). For example, in 2005 catches of *Tabanus* spp. were highest in Nzi traps and lowest in MA traps (3.2 per trap-day versus 1.8 in the MA trap; 2.7 in the GH trap with a decoy, zero without a decoy). For all data for the two common *Tabanus*, the ratio of catches of *T. similis* to *T. quinquevittatus* Wiedemann was very low in the GH trap (GH: *Ts:Tq* ratio of 0.4 versus ratios of 1.4 in the Nzi trap and 3.9 in the MA trap). The MA trap was particularly effective for *Hybomitra lasiophthalma* (Macquart) with 23% of the tabanid catch consisting of this species versus 6% in the Nzi trap and 1% in the GH trap. The Nzi trap was the only trap that consistently caught a variety of *Chrysops* (13 species), including several human-biting species (*Chrysops cinc-*

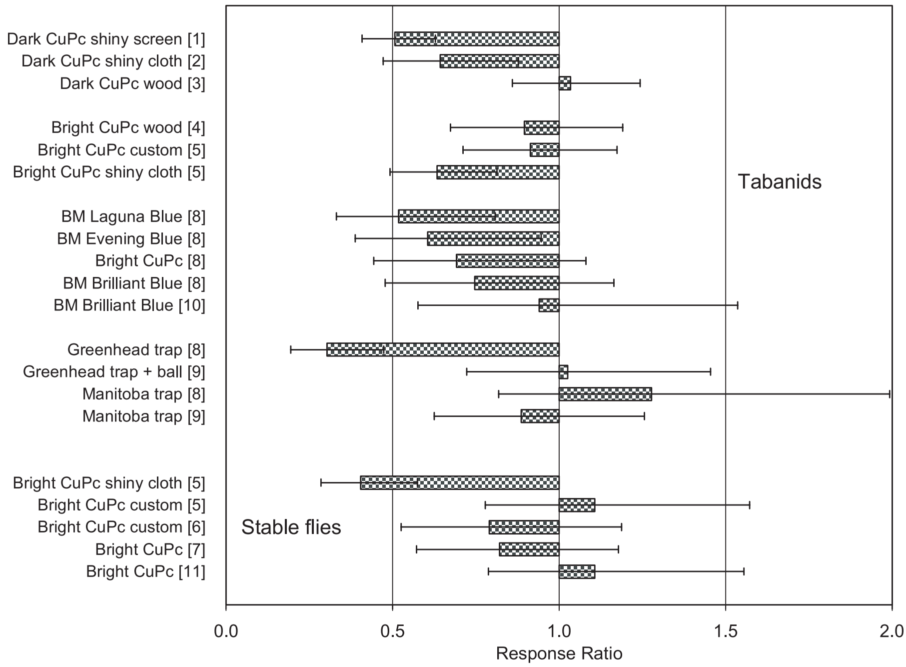

Fig. 4. Response ratios (R, mean ± 95% confidence interval) of tabanids and stable flies in painted Nzi traps, and Manitoba and greenhead traps relative to a standard phthalogen blue cloth Nzi trap (STD). Experiment numbers are in brackets.

ticornis Walker, *Chrysops aberrans* Philip, and *Chrysops univittatus* Macquart).

Stable flies were seasonally present in four experiments when only Nzi traps were being compared (Fig. 4; $GM_c = 3.9–4.5$, maximum 31). In these experiments, a painted cloth trap with a shiny texture caught very few stable flies. In contrast, painted plywood traps in two bright CuPc formulations caught as many stable flies as a STD trap in all four tests. In Florida, recovery of stable flies in sticky box traps with adhesive panels in an outdoor enclosure was considered excellent (76%). Differences in catch among treatments were not significant ($F = 0.75$, df = 3, 99, $P = 0.53$); with no more than an 11% difference in catch with any paint color compared with Sunbrella cloth (R from 0.92 to 1.11, $GM_{cloth} = 11.3$).

Discussion

Plywood Nzi traps in matching flat acrylic paints performed as well as phthalogen blue cloth traps for both tabanids and stable flies. However, paints with a shiny texture on cloth, or the use of aluminum screening, reduced catches of these two groups of biting flies. Overall, effective painted traps can be prepared with any flat paint that contains mostly blue tint as long as paint is applied to a well-textured surface such as plywood. A color saturation range of ≈20–40% peak reflectance seems suitable. Any paint similar to BM Brilliant Blue can be chosen through color matching software (R = 0, G = 100, B = 166) (Logicol 2006). CuPc is the typical blue pigment used in most industrial colorants (Herbst and Hunger 2004).

Further research on biting flies is still appropriate to determine whether CuPc is indeed the best pigment for attraction in terms of both hue and color saturation. We focused on bright CuPc blues based on the use of bright phthalogen blue cloth in tsetse traps, and higher catches with brighter mixtures of a blue oil paint in a study of greenhead behavior toward sticky panel traps (Allan and Stoffolano 1986). Similar data have yet to be compiled for stable flies, because previous researchers have only tested responses to generic colors (Agee and Patterson 1983, Cilek 2003).

To expand on limited previous trap comparisons in Canada, two contrasting styles of conventional traps were tested relative to Nzi traps. Previously, a black-skirted canopy trap with a white netting canopy (Hribar et al. 1991), with or without a black ball decoy, caught very few tabanids relative to a Nzi trap (Mihok et al. 2006). Here, an MA trap, with a transparent plastic canopy and a much larger decoy, caught as many tabanids as the Nzi trap, but with a likely bias for *Hybomitra* relative to *Tabanus,* and with low captures of *Chrysops* (Hanec and Bracken 1964). *Hybomitra* is not self-evident at Russell; the genus accounts for only 9% of the tabanids feeding on cattle nearby (Lewis and Leprince 1981). Use of a decoy proved essential for catching *Tabanus* with the GH trap, which caught no *Hybomitra* or *Tabanus* without a decoy. This was unexpected, because even plain box traps catch many horse flies at other locations (Axtell et al. 1975, Foil 1999).

In conclusion, this study has shown that an appropriately painted plywood Nzi trap can be used to catch tabanids and stable flies. Given the good performance of cloth Nzi traps for biting flies elsewhere, this result should be valid for other fauna in other environments. The advantage of a plywood trap is that it can be made from readily available materials, while providing a flexible and robust option for fixed applications. A plywood trap costs ≈$50 if minimal hardware is used (e.g., netting can simply be stapled to the body). This is about the same cost as a trap made from Sunbrella fabric, which is the only suitable, color-fast substitute for phthalogen blue cotton available in North America (Mihok et al. 2006).

Acknowledgments

We thank A. Broce and J. Cilek for comments on the manuscript.

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Received 17 May 2006; accepted 23 October 2006.